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(54) Abstract Title

Image comparison in transform-quantised space

(57) A video compression codec implementing 'on-off' differential compression performs a comparison between a block of the present frame and the most recently encoded corresponding block from a previous frame wherein both present and previous blocks have been subjected to transform coding (particularly DCT) and quantisation (Q). A standard JPEG processor may be used for the transform and quantisation but as this will also include an entropy coder, the signals require entropy decoding prior to comparison (Figure 4).

The invention has the advantage of not requiring any decoding of a transformed signal to provide a comparison.

ordered

2 sequenced w/values associated with category & magnitude

Fig. 3

col. 6,
l. 8-13

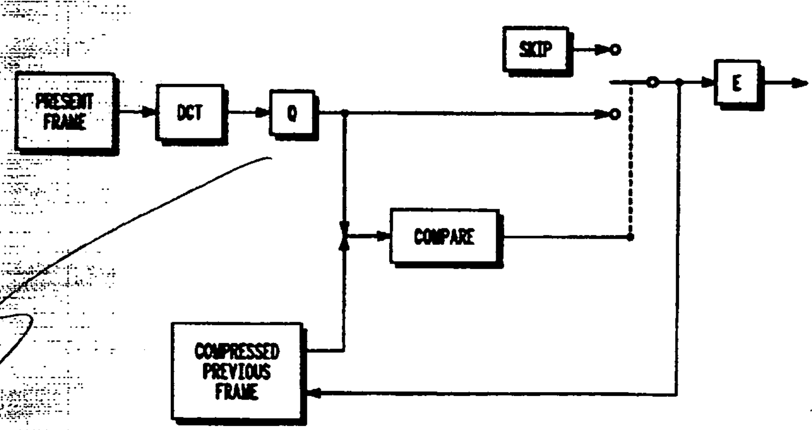

FIG.3

See e.g. P. 81 of
Image & Video Compression Standards (2nd ed.; 1997)
by Bhaskaran et al.
for quantization coefficients.

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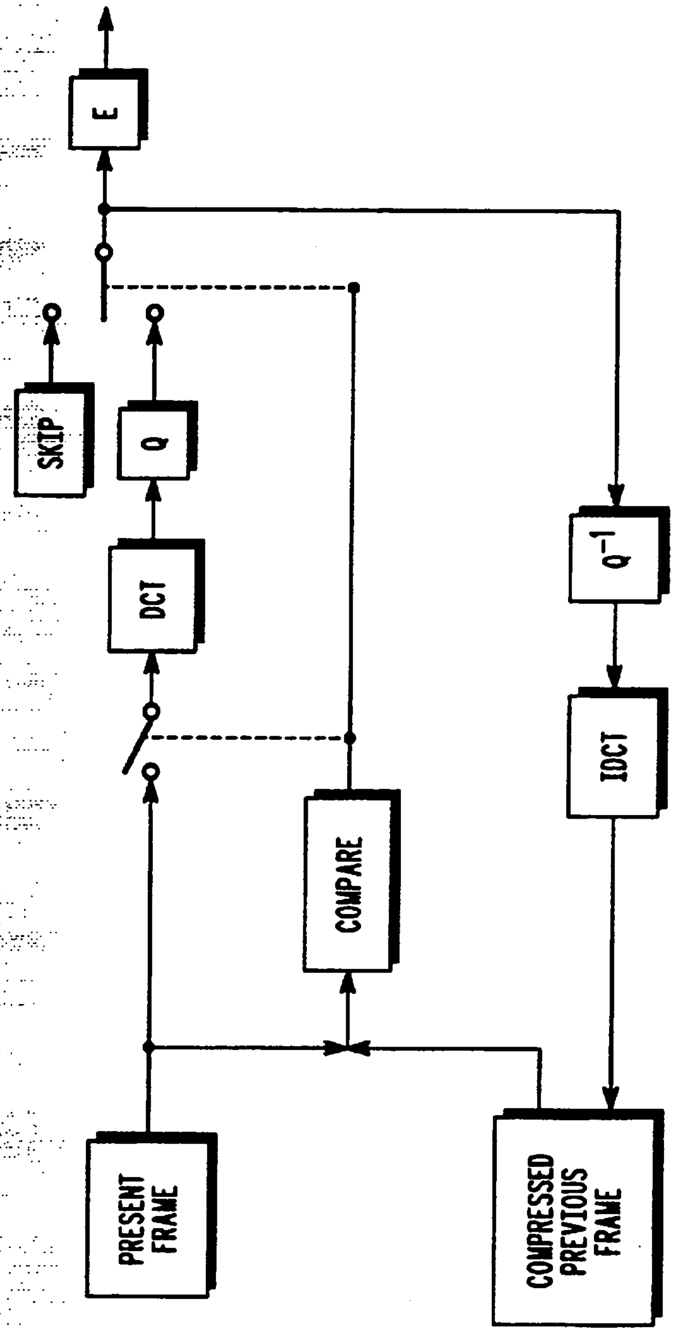
E
SKIP
Q
DCT
Q-1
IDCT
COMPARE
PRESENT FRAME
COMPRESSED PREVIOUS FRAME

FIG. 1

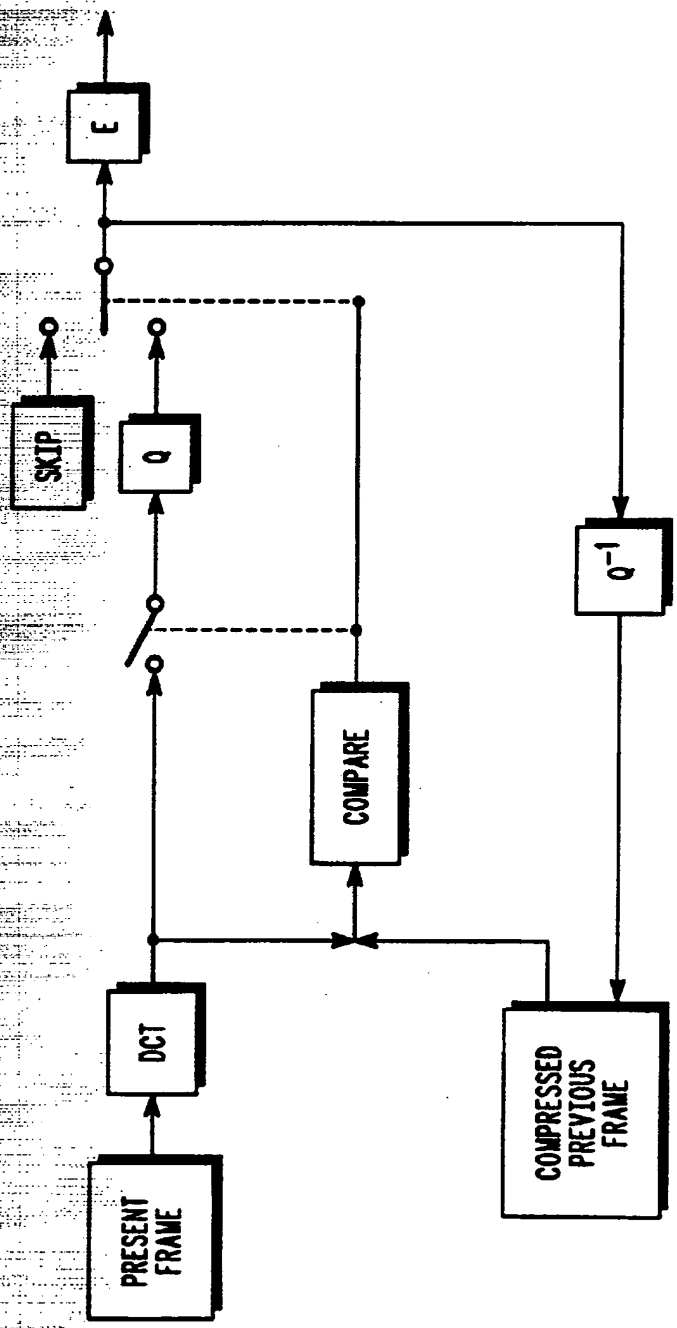
E
SKIP
Q
COMPARE
Q^{-1}
DCT
PRESENT FRAME
COMPRESSED PREVIOUS FRAME

FIG. 2

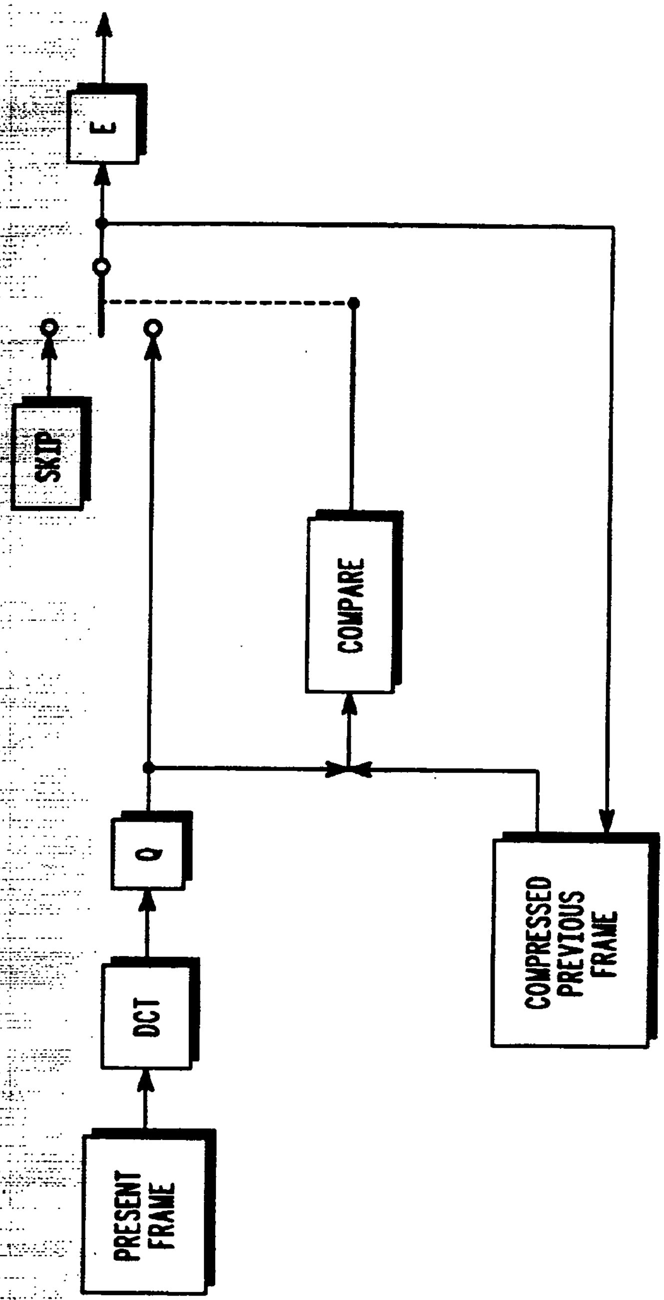
E
SKIP
COMPARE
Q
DCT
PRESENT FRAME
COMPRESSED PREVIOUS FRAME

FIG.3

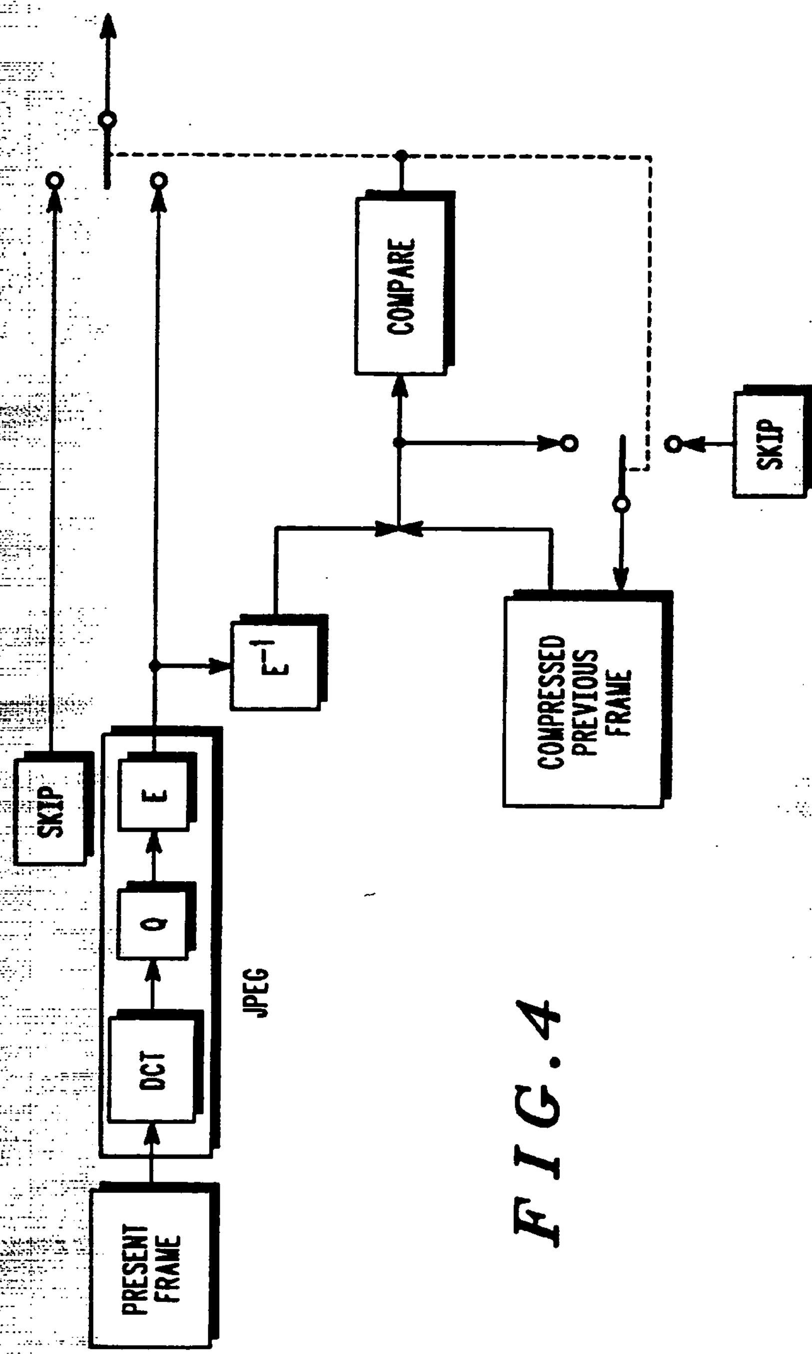
PRESENT FRAME
DCT
Q
E
JPEG
SKIP
E⁻¹
COMPARE
COMPRESSED PREVIOUS FRAME
SKIP

FIG. 4

Video codec and method for encoding video frames

Technical Field

The invention relates to the field of video codecs. In particular, the invention concerns the comparison of image frames in a video codec.

Background

Video codecs are used to prepare video image frames for transmission. In the remainder of this description, 'video' will be used to mean motion video. 'Image' will be used to describe a single image.

Conventional JPEG video compression does not enable exploiting the time redundancy in the compression of video sequences. Each frame in the video sequence is compressed independently from its neighbours in time.

However, modern video codecs compare consecutive video frames and encode only the difference between the present frame and the previous frame. In a video transmission system, such selective encoding reduces the amount of information which must be transmitted. This encoding is referred to as 'compression'.

In the rest of this document, Discrete Cosine Transform (DCT) based video coders will be considered unless stated otherwise. In these codecs the frame is divided into blocks of fixed size. These blocks consist generally of 8x8 or 16x16 pixels. Each block is compressed separately in video standards such as MPEG-I, MPEG-II, H.261, and others based on this principle.

A video codec which carries out video compression is commonly termed an encoder. Similarly, a video codec which carries out video de-compression is commonly termed a decoder.

Simple codecs use an on-off technique for the encoding. This technique involves comparing corresponding blocks of consecutive images and if they are similar then the latest block is not encoded. Instead the system generates and transmits information to the effect that this block is a duplicate of the corresponding block from the previous frame. If however the latest block is sufficiently different from the corresponding block of the earlier image, then the block concerned is encoded as is.

This 'on-off' differential video compression is illustrated in figure 1.

Figure 1 shows the generic block diagram of a video compressor based on DCT and implementing on-off differential encoding technique. Each block from the present frame is compared to the most recently encoded corresponding block from a previous frame. The most recently encoded block from a particular position in the frame and its frame will be referred to as the 'previous block' and 'previous frame' respectively. These will only be from the immediately preceding frame when the corresponding block in that frame was in fact encoded.

The comparison performed by the arrangement of figure 1 is performed in 'image space'. This means that the comparison is performed between data concerning the latest image frame, which has not yet been processed for transmission, and data from the previous image frame, which has both been processed for transmission and then also processed back into its original format. The decision whether or not to encode a block of a video frame is therefore made by comparing two portions of images themselves.

If the present block and the previous block are similar, then the output of the encoder is a signal indicating that no encoding of the present block will take place. This has been shown in figure 1 as a 'Skip' block. This signal may consist of a single byte of data. Obviously transmission of this byte in place of the code for an entire block reduces the requirements, particularly for bandwidth, on circuitry and transmission paths downstream of the codec.

However, if corresponding blocks in the present and previously encoded image are not similar, then the present block must be encoded. The present block is DCT transformed by the element marked DCT, the resultant coefficients are quantised by element Q, and the quantised coefficients are compressed using an entropy compressor, element E. This entropy compressor may in fact include any lossless encoding steps such as run-length coding, Huffman coding etc.

The comparison carried out by the 'compare' block in figure 1 is made in order to decide whether or not to encode a particular block of the latest image. This comparison must be done in image space when motion estimation compensation is used in the compressor. This is the reason why the arrangement of figure 1 converts the block of the previous compressed frame back into image space. The elements IDCT and Q^{-1} are employed to do this. Element IDCT provides an inverse DCT transform of the coefficients which are input to it. Element Q^{-1} is a de-quantiser. Together elements IDCT and Q^{-1} constitute a partial decoder.

There are however encoding arrangements where motion compression can be omitted. In these cases it is not necessary to perform the comparison of image blocks in image space. Instead the comparison can be performed in DCT coefficient space, also referred to as the DCT 'domain'. To perform such a comparison, it is not necessary to perform an inverse DCT operation on the coefficients of the previous block. An arrangement for on-off differential video compression in the DCT domain is shown in figure 2.

The major differences between figures 1 and 2 are that:
(i) In the arrangement of figure 2, the compressed previous image block is in DCT coefficient space when the comparison is made between the latest and the previous blocks;
(ii) In the arrangement of figure 2, all blocks pass the DCT;
(iii) The arrangement of figure 2 does not include an IDCT element for performing an inverse DCT transformation in the decoding branch.

Function of the comparators

The function of the comparator of figure 1 is to compute the energy of the differences between a block from the present frame and the corresponding block from the previous frame, in image space. If the energy difference is not computed, then the 'compare' block must calculate the difference in a similar variable between the two blocks. The comparator in figure 2 performs the same computations in DCT coefficient space.

Summary of the Invention

A video compressor (DCT; Q; E) in accordance with the invention comprises means for comparing present and previous video frames, whereby the means for comparing are adapted to make the comparison in quantised (DCT; Q) coefficient space.

In accordance with a preferred embodiment of the invention, the video compressor (DCT; Q; E) comprises an entropy decoder (E^{-1}) for providing the data concerning the previous frame in quantised (DCT;Q) coefficient space. The video compressor may comprise transform means (DCT) for applying a DCT transform to blocks of the video frames and quantising means (Q) for converting the output of the transform means into coefficients in quantised space.

A video transmission system (JPEG) in accordance with the invention may comprise a video compressor (DCT; Q; E) in accordance with any of the above embodiments and a data transmitter for transmitting the compressed data.

A method of video compression (DCT; Q; E) in accordance with the invention may comprise comparing present and previous video frames, whereby the comparison is made in quantised (DCT; Q) coefficient space.

In accordance with a preferred embodiment of the invention, the method of video compression may comprise the step of providing the data in quantised coefficient space concerning the present frame by entropy decoding (E^{-1}). A DCT transform (DCT) may be applied to blocks of the video frames and the output of the transforming step may be quantised (Q) into coefficients in quantised space.

A method of video transmission (JPEG) in accordance with the invention may comprise performing video compression (DCT; Q; E) in accordance with any of the methods outlined above and transmitting the compressed data.

Brief description of the drawings

Figure 1 shows a prior art arrangement for performing 'on-off' differential video compression in image space;

Figure 2 shows an arrangement for performing 'on-off' differential video compression in the DCT domain;

Figure 3 shows an arrangement for performing 'on-off' differential video compression in accordance with the invention;

Figure 4 shows an arrangement for performing 'on-off' differential video compression in pre-dequantisation DCT domain in accordance with the invention, together with a complete JPEG compression system.

Detailed description of the preferred embodiment

The video compressors presented in figures 1 and 2 necessitate the existence of either full or partial decoders in the backward path of the compression side. In figure 1 this decoding is performed by the elements Q^{-1} and IDCT. In figure 2 this decoding is performed by element Q^{-1}. Without such decoding, the

information in the previous frame would not be in the same 'space' as the information about the present frame with which it must be compared.

However, in an arrangement in accordance with the invention the backward path can be simplified even further, to become only a null operation. To do this, the structure of the compressor is as in Figure 3.

In the arrangement of figure 3, the compressed previous frame is saved in the pre-dequantization DCT coefficients space. Consequently, all blocks of the present frame pass the DCT and the quantiser Q before the comparison. The movement of the quantizer to this new position enables the removal of the inverse quantizer Q^{-1}. As a result, the backward path of the compressor does not involve any operation at all.

In Figure 3 the compressed previous frame is in pre-dequantization DCT coefficients space. Since the step of quantising introduces error, the comparison to be done in Figure 3 is not identical to that done in either figure 2 or figure 1. To see the distinction, in the following, the sum of absolute difference SAD will be used as the comparison measure.

In Figure 2 the SAD of an 8x8 block is calculated according to the following equation:

$$SAD = \sum_{i=0}^{7} \sum_{j=0}^{7} \left| c_{ij}(t) - q_{ij} e_{ij}(t-1) \right| \qquad \text{(Equation 1)}$$

where:

i and j are index numbers of the pixel;

$c_{ij}\,(t)$ is the DCT coefficient for the pixel ij of the present frame;

q_{ij} is the quantization step; and

e_{ij}(t-1) is the pre-dequantization value of the corresponding coefficient for the previous frame.

In Figure 3 the SAD per block is calculated according to the following equation:

$$SAD^p = \sum_{i=0}^{7} \sum_{j=0}^{7} \left| e_{ij}(t) - e_{ij}(t-1) \right| \qquad \text{(Equation 2)}$$

SAD^p is the pre-dequantization SAD. The absolute value term in equation 2 can be multiplied and divided by q_{ij}

$$SAD^p = \sum_{i=0}^{7} \sum_{j=0}^{7} (1/q_{ij}) \left| \hat{}c_{ij}(t) - q_{ij}\, e_{ij}(t-1) \right| \qquad \text{(Equation 3)}$$

Here $\hat{}c_{ij}(t)$ is the dequantised DCT coefficient.

There are two main differences between equations 1 and 3. The first difference is the value of the DCT coefficient for the present frame. For unbiased quantizers the average error between original and quantised values is zero.

The second, more important, difference results from the weighing factor of $1/q_{ij}$ at the beginning of equation 3. If the value of the quantization step q_{ij} takes larger values as the spatial frequency increases, we observed that, in SAD^p, more importance is given to low frequency coefficients. This is the main degradation between SAD^p and SAD.

However, the human visual system is more sensitive to lower spatial frequencies, so the weighing in equation 3 should not degrade the performance of the comparison. As evidence of this, simulations have shown that the degradation in performance is negligible. The result is that the visual quality of each of the compressed images, according to both schemes, is almost the same.

An advantage of the innovation suggested in figure 3 becomes clear when a closed compression engine (JPEG engine) is available and on-off differential coding is required.

For this case, the complete block diagram of an arrangement in accordance with the invention is shown in Figure 4. The blocks DCT, Q and E represent the JPEG compressor. This compression engine does not allow access to any intermediate connection point. Hence, the pre-dequantization DCT coefficients are obtained only by applying an entropy decoding operation. This operation is carried out by the block marked E^{-1} in figure 4. The comparison between the present and previous image blocks is made according to equation 2. The result of the comparison affects two data paths.

In the arrangement in accordance with figure 4, if the blocks under comparison are similar the skipping information is passed as the compressed data. Also, the corresponding block in the compressed previous frame is retained unchanged for the comparison. If however the comparison detects significant change then the output of the JPEG engine is passed as the compressed data. Also, the corresponding block in the previous frame used for the comparison step is updated by replacing it with the output of the entropy decoder E^{-1}.

If the comparison had been done in the DCT coefficients space then, in addition to the entropy decoder, it would have been necessary to apply dequantisation. This additional operation would have added one multiplication operation per DCT coefficient. Therefore by applying the comparison on the pre-dequantization DCT coefficients all these multiplication operations are saved. This saving enables the use of less powerful hence cheaper computation devices.

The apparatus in accordance with the invention can take many forms. A digital signal processor could be provided. However, a suitably programmed general purpose CPU could also carry out the steps of the invention. It is only necessary for the apparatus to have functional elements which can carry out the operations shown in figure 3. Typically the invention may be applied to an existing JPEG compressor as shown in figure 4. In this case, the apparatus must have functional elements capable of carrying out the entropy decoding step of element E^{-1}.

To transmit the compressed data, transmission means are required. The transmission means may be an RF modem or a line modem. The exact choice of transmitter depends on the medium and distance through which the data is to be sent. In application to TETRA, the transmitter will be that in the radio base station or that in the user's portable or mobile radio.

The following points should be noted in connection with the invention:
(i) The invention relates to differential image compression based on 'on-off' technique. According to the invention, the comparison between a block from the present frame and the corresponding block from the previous frame is done in quantised, i.e. pre-dequantisation DCT coefficient space.
(ii) When the quantisation steps vary for different DCT coefficients, especially when adjusted according to the human visual system, the comparison automatically puts more emphasis on DCT coefficients for which the quantisation step is smaller.
(iii) In the method and apparatus in accordance with the invention, the previous frame is saved in pre-dequantisation DCT coefficient space. This means that it is the frame which was most recently compressed, or a block of that frame, which is held for comparison with newly arriving frames or blocks of frames. The frame held is updated each time a decision is made to encode the latest frame to arrive. This comparison technique saves the computation which would have been required for dequantisation if the actual quantised coefficient values of the present and previous frames had been used in the comparison.
(iv) In the basic arrangement of the invention in accordance with figure 3, the entropy encoding is applied only to the blocks for which significant changes have been detected.
(v) The block skipping information is either separately encoded or multiplexed with the entropy encoded bit stream.
(vi) Although theoretically different, comparison using pre-dequantization DCT coefficients achieves almost the same compression performance as comparison using actual DCT coefficients. The visual quality of the resultant image is almost indistinguishable for the two techniques.

Claims

1. A video compressor (DCT; Q; E), comprising:

means for comparing present and previous video frames; whereby

the means for comparing are adapted to make the comparison in quantised (DCT; Q) coefficient space.

2. A video compressor (DCT; Q; E) according to claim 1, comprising

an entropy decoder (E^{-1}) for providing the data concerning the previous frame in quantised (DCT;Q) coefficient space.

3. A video compressor (DCT; Q; E) according to claim 1 or claim 2, comprising

transform means (DCT) for applying a DCT transform to blocks of the video frames; and

quantising means (Q) for converting the output of the transform means into coefficients in quantised space.

4. A video transmission system (JPEG) comprising a video compressor (DCT; Q; E) in accordance with any previous claim and a data transmitter for transmitting the compressed data.

5. A method of video compression (DCT; Q; E), comprising:

comparing present and previous video frames; whereby

the comparison is made in quantised (DCT; Q) coefficient space.

6. A method of video compression (DCT; Q; E) according to claim 5, comprising the step of:

providing the data concerning the present frame in quantised coefficient space by entropy decoding (E^{-1}).

7. A method of video compression (DCT; Q; E) according to claim 5 or claim 6, comprising the steps of:

applying a DCT transform (DCT) to blocks of the video frames; and

quantising (Q) the output of the transforming step into coefficients in quantised space.

8. A method of video transmission (JPEG) comprising performing video compression (DCT; Q; E) in accordance with the method of any of claims 5-7 and transmitting the compressed data.

The Patent Office

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Claims searched: All

Examiner: Sue Willcox
Date of search: 13 January 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H4F (FRT, FRG, FRC)

Int Cl (Ed.6): H04N (7/30)

Other: Online databases: WPI, Japio

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2308772 A (Daewoo Electronics Co., Ltd) see particularly page 11 line 25 et seq	1, 3, 4, 5, 7, 8

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.